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R E S E A R C H A T A G L A N C E

Genetic Resource Policies

What is Diversity Worth to Farmers?

Melinda Smale and Amanda King

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IFPRI was established in 1975 to identify and analyze national and international strategies and policies for meeting the food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and poor people; to make the results of its research available to all those in a position to use them; and to help strengthen institutions conducting research and applying research results in developing countries.

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IPGRI is an international research institute with a mandate to advance the conservation and use of genetic diversity for the well-being of present and future generations. Founded in 1974, IPGRI is the world's largest international institute dedicated solely to the conservation and use of plant genetic resources, with a staff of over 170 in offices around the world. IPGRI's mission is to encourage, support and undertake activities to improve the management of genetic resources worldwide so as to help eradicate poverty, increase food security, and protect the environment.

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ABOUT RESEARCH AT A GLANCE AND THIS SERIES

Researchers and policy analysts increasingly need concise, comprehensive information on all aspects of complex research issues. IFPRI's Research at a Glance series has been designed to meet this need. This volume contains the third of a series of IFPRI briefs on genetic resource policies. The first set, published in January 2003 and containing Briefs 1 through 6, focuses on intellectual property rights issues, the second set, published in December 2003 and containing Briefs 7 through 12, focused on issues related to *ex situ* genebanks and their collections, and this third set sheds light on questions regarding who maintains diversity, where it is maintained, and how farmers value this diversity as societies and economies change. These briefs present syntheses and synopses of research conducted by IFPRI's Environment and Production Technology Division along with multiple collaborators.

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Cover photo credits

The cover collage represents the collaborative efforts of researchers and farmers whose work in the field, the laboratory, and in gene banks helps to sustain agricutlural biodiversity for current and future generations. The collage background image, generated by Damian Jaccoud (a student working under the supervision of CAMBIA's chief scientist, Andrzej Kilian), represents a Diversity Array Technology (DArT) image, a form of "DNA on a chip" technology developed by CAMBIA for low-cost genome analysis; the rice farmer image was generated by Amanda King of IFPRI.

RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 13

Introduction: On–Farm Genetic Resources and Economic Change

Melinda Smale and Amanda King

In agricultural systems, a diversity of crops and varieties is needed to combat the risks farmers face from pests, diseases and variations in climate. Crop biodiversity also underpins the breadth of dietary needs and services that consumers demand as societies become wealthier. For some time, scientific experts have been concerned about declining diversity of crop genetic resources on farms. Many argue that the very processes that engendered the remarkable advances in agricultural productivity during the 20th century, such as the Green Revolution, also eroded the valuable stocks of genetic resources long maintained by farmers. Sampling these resources and housing them in gene banks, while fundamental, is only a partial solution. Ex situ conservation stops the evolutionary clock and raises proprietary concerns as genetic material is transferred out of the hands of its historical custodians for safeguarding.

Economists often view the loss of diversity as an unavoidable, unintended consequence of technical change and specialization—a negative externality of progress. The underlying premise of the research described in Briefs 13 through 18 is that in the longer term, managing crop genetic diversity through a combination of strategies and approaches (in gene banks, breeding programs and on farms) is essential for sustained social and economic development.

The research on which the briefs are based has been published as a collection of case studies geared toward agricultural and resource economists, applied researchers working in international and national organizations, and scientists involved in local plant breeding and genetics (Smale, 2006). Largely interrelated in methods and approach, the case studies were implemented across a range of crops and agricultural economies where crop biodiversity of global economic value remains in the fields of farmers. Developing economies in Asia, Latin America, and Africa are represented, as well as transitional and richer economies in Europe. Crops investigated include maize, rice, durum wheat, sorghum and millet, potato, highland banana, coffee, fruit trees, grapes, and nuts.

In this collection of case studies, researchers shed light on questions regarding "who" maintains diversity, "where" it is maintained, and "how much" farmers value this diversity as societies and economies change. By identifying the factors that influence the likelihood that farmers will continue to manage crop biodiversity in a given context, the case studies suggest how conservation programs might be designed and appropriately targeted. The findings indicate how factors such as human capital, off-farm income and migration, assets, farm physical conditions, and involvement in product and seed markets influence the way farmers value the attributes of crops and varieties. In addition, the studies employ higher scales of analysis than previous research on this subject, incorporating the role of institutions at the levels of villages, settlements and regions. Greater comprehen-

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sion of these relationships will help to guide researchers and policy makers in the identification of practical entry points to support both conservation of genetic resources and rural development.

Understanding What Farmers Value

This series focuses on the value of crop and variety diversity to the farmers who manage it. The diversity of crops and crop varieties is a consequence of human choices in close interaction with natural selection. Farmers choose to grow particular crop varieties for the specific qualities they seek, which include production traits such as crop yield and tolerance to pests and diseases, as well as consumption-related attributes such as taste and processing qualities.

The economic value of increasing crop productivity through the diffusion of improved, modern varieties has been extensively documented, particularly in the context of industrialized agriculture (e.g., Alston et al., 2000; Evenson and Gollin, 2003). Costs and benefits have also been estimated for plant genetic resources conserved in gene banks, destined principally for use by commercial farmers (Koo et al. 2004; see Briefs edited by Smale and Koo). In contrast, scant economics research has sought to understand the value of increasingly scarce, local varieties to the farmers who grow them. This is partly because such varieties are typically found in marginal, isolated environments, where they are traded outside of formal markets. In addition, economists have only recently challenged the commonly-held assumption that local varieties will inevitably be replaced by modern varieties over time (Brush et al. 1992; Meng 1997).

Local varieties, often called landraces, generally exhibit high degrees of local adaptation, with particular properties or characteristics that are valuable to the communities in which they are grown and potentially valuable for crop improvement elsewhere, where they may be scarce. Landraces are often highly variable in appearance and show considerable genetic variation, which is often deliberately manipulated by farmers (Harlan 1992).

Seed is an impure public good, with both private and public characteristics (Heisey et al., 1997; Morris 1998). While it has value as a production input for individual farmers, there are also public values associated with the crop genetic diversity that it contains. One example is the option value that genetic resources provide, or flexibility to deal with unexpected future demand. Since the genetic diversity of crop genetic resources is not fully transparent to the farmers who manage it, individual decisions on the use and management of crop varieties can result in the loss of potentially valuable resources. In developing strategies to sustain agricultural biodiversity in ways that are beneficial to both society and the farmers who manage genetic resources, the greatest benefits and the lowest costs will arise in economic and physical environments in which both the benefits for farmers and the public value of crop diversity are high.

Elements of the Approach

Diversity Metrics

A novel aspect of the economics methods applied in these studies is the attention given to the concept of diversity. Diversity can be measured in a variety of ways, and diversity indices are used to represent various concepts. No concept is universally correct, and more than one may be appropriate in any particular context (Meng et al. 1998), underscoring the need to work in close interaction with genetics experts and crop scientists. For example, the diversity that is "apparent" to farmers in the physical characteristics of crop populations differs from the "latent" diversity revealed through molecular or pedigree analysis. In addition, crop biological diversity can be measured within or between species, and over space and time. The crop reproduction system is a critical aspect to consider when choosing a metric of diversity, as is the nature of the farming system. For example, diversity indices based on pedigree data cannot be constructed for landraces.

The diversity concept (latent or apparent; spatial or temporal) is distinguished from the measurement tool that enables the concept to be incorporated into an economic model as a diversity index (Meng et al. 1998). Diversity indices are scalar variables constructed from any one of several types of data. For example, data may record physical measurements on crop plants grown in controlled experiments or may document the variation in DNA taken from plant tissue and expressed as patterns on gels. With the exception of the trait-based index described in Brief 14, the diversity indices in the case studies were adapted from ecological indices that express spatial diversity concepts for species: the Margalef index, which measures species richness; the Berger-Parker index of dominance, which measures relative abundance; and the

Shannon index, which represents both richness and relative abundance.

While understanding latent diversity is of routine importance for crop breeding and conservation programs, the authors of these studies purposefully chose to use the units of diversity that farmers recognize and manage as the basis for constructing diversity indices. Because farmers tend to grow varieties based on the traits and attributes they observe rather than those they cannot see, the more sophisticated the construction of the diversity index, often the more obscure is its relationship to the decisions of farmers. In order to understand farmer-managed units of diversity, variety names were taken as a starting point. However, because variety names are largely cultural artefacts and can mask redundancy, most of the studies presented in the following briefs cross-checked variety names with morphological characteristics and genetic information in order to generate more comprehensive taxonomies (see Brief 14).

Analytical approaches

To analyze farmer decision-making and assess private value to farmers, data were collected through cross-sectional surveys of farm households across villages in subnational regions. Analytical approaches were adapted from agricultural economics, environmental economics, and institutional economics, which together portray the relationships among: 1) the determinants of crop diversity levels on farms; 2) the value of specific crop varieties and their attributes to farmers; and 3) predicted changes caused by contextual factors such as new economic policies, rural development programs, seed interventions, market development, and other institutions.

Many of the authors of the case studies base their analyses of determinants of diversity on a household model of on-farm diversity (Van Dusen 2000). This approach is suitable for analyzing the decisions of subsistence-oriented farmers in economies where markets are unreliable. The household is portrayed as a producer of agricultural goods and services either for home consumption or sale, which is subject to resource and market constraints. The dependent variables in the models are the diversity metrics, and explanatory variables are defined by a combination of microeconomic theory, principles of population genetics, and ecology.

The crux of the approach is the magnitude of the costs of transacting in markets, which depend on the unique characteristics of each household, such as its composition, education and experience levels, and wealth. When transaction costs are so high that households do not participate in markets, consumption decisions cannot be separated from production choices. That is, household and market characteristics, in addition to farm physical characteristics, will drive variety choices and, as a consequence, crop diversity levels on farms. An extension of this approach by Edmeades et al. (2003) incorporates traits as well as the characteristics mentioned above. Using this approach, the authors demonstrate that both the consumption and production attributes of banana planting material influence the richness of banana varieties maintained by Ugandan farmers (see Edmeades et al., Brief 14).

These models relate farmer choices to factors representing economic and social change, and can be used to predict those households or villages most likely to continue to grow diverse crops and varieties. Although they cannot provide monetary estimates of value, they can be used to identify varieties with high private value. Such information is useful for designing least-cost conservation programs.

Stated preference approaches provide monetary estimates of the value of genetic resources based on hypothetical scenarios—the “how much” rather than the “who” or “where.” They enable us to value goods that do not have prices. Two recent advances in environmental valuation are the choice experiment (Brief 15, Birol et al.) and a contingent behavior approach (Brief 15, Dyer). The first provides a monetary measure of the amount farmers would need to be compensated for loss of landraces or other attributes of home gardens in Hungary’s transitional economy. The second approach is used to estimate the impact on maize landrace cultivation of a hypothetical change in maize price due to the North American Free Trade Agreement.

The choice experiment method provides four pieces of policy-relevant information for crop genetic resources: 1) which attributes are significant determinants of the private value of the asset; 2) the relative ranking of these attributes in terms of their importance; 3) the value of simultaneously changing more than one of the attributes; and 4) an estimate of the total economic value of the asset. The technique has several distinct advantages over the contingent valuation approach commonly used by environmental economists to value non-market goods. Nevertheless, it shares the essential drawback of the household farm model: the need for intensive, primary data collection. Moreover, any hypothetical approach has the obvious weakness that it seeks to measure the consequences of an event that has not transpired.

Institutions, ranging from local norms of access and exchange to seed markets, national breeding programs, and international proprietary regimes for plant genetic resources, are the purveyors of the public goods embodied in seed. Institutional analysis is a means of linking the decisions of individual farm households to crop biodiversity observed at more aggregated levels of analysis, such as the identification of seed supply channels and actors. For example, stakeholder analysis aims to identify key actors or stakeholders of a system or a problem under examination. Mapping and stakeholder analysis situates households within the context that proscribes their behavior and that they themselves can influence. In the context of research on crop diversity, stakeholder analysis also facilitates understanding of barriers in access to seed as well as related information. The textual analysis presented by Bela et al. (Brief 17) illustrates the dis-

Table 1—Dimensions of crop biodiversity

Country	Income Group[2]	Farming system	Crop	Crop reproduction system	Unit of (level or scale)	Diversity concept[1]
Ethiopia	Low	mixed modern and traditional	cereals (maize, wheat, barley, teff, finger millet, pearl millet, sorghum); coffee; wheat and maize, multiple crops	range of self and crosspollinating rates; vegetative	household and plot; village; some regional variables	intracrop or intercrop
Nepal	Low	focus on traditional	rice	highly self-pollinating	household and plot; breeding program some ecosite variables	intracrop
Uganda	Low	mainly traditional	highland banana	vegetative	household and plot; some village and regional variables	intracrop
Uzbekistan	Low	microecosystem; mixed modern and traditional	fruit trees, grapes and nuts	vegetative	household and plot	intracrop and intercrop
India	Low	mixed modern and traditional	sorghum, pearl millet, finger millet, other minor millets	range of self- and cross-pollinating rates	village; some household variables some district variables	intercrop and/or intercrop
Peru	Lower middle	mixed modern and traditional	potato	vegetative	household; some regional variables	intracrop
Hungary	Upper middle	microecosystem; mixed modern and traditional	home gardens; maize and beans	all systems	household and plot; settlement; some regional variables	intracrop and/or intercrop
Mexico	Upper middle	milpa microecosystem	maize only; maize beans and squash	highly cross-pollinating	household and plot; some village and regional variables	intracrop and intercrop
Italy	High	mixed modern and traditional	durum wheat	self-pollinating	region	intracrop

1 All studies base the classification of varieties on farmer and/or breeder taxonomies. Diversity indices are spatial.

2 The World Bank (2004) defines GNI per capita as "the gross national income, converted to U.S. dollars using the World Bank Atlas method, divided by the midyear population. Low-income economies had GNI per capita of $735 or less in 2002; middle-income economies had more than $735 but less than $9,076; lower-middle-income and upper-middle-income economies are separated at $2,935; high-income economies had $9,076 or more."

sonance of vocabularies and views that stakeholders hold regarding genetic resources. Such analyses may also contribute to the process of articulating strategies to resolve conflicts and to the creation of more effective policies for on-farm conservation.

Series Structure

The following briefs are organized to highlight some of the most important methodological aspects of current work on valuing genetic resources on farms, and the factors that influence the determinants of crop genetic diversity. Brief 14 provides additional discussion on the construction of crop taxonomies and models that incorporate crop attributes. Brief 15 outlines several studies that identify the role of crop diversity in situations of economic change, particularly those related to processes of market integration. Brief 16 summarizes research that deals particularly with the trade-offs between conservation and policy objectives, while Brief 17 describes studies that focus on seed-related institutions and their impact on the crop diversity that is available to farmers. Finally, brief 18 provides a reprise of the variables that serve as potential entry points for conservation-related interventions or policy development.

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RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 14

TRAITS AND TAXONOMIES—BUILDING BLOCKS FOR UNDERSTANDING DIVERSITY

Melinda Smale and Amanda King

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What's in a name?

Farmers and scientists start with different perspectives about the plants they breed and manage, and their ways of ordering or classifying them, called "taxonomies." Linking these differing perspectives poses a challenge in applied research about on-farm management of crop genetic resources.

Farmer taxonomies and nomenclature are typically localized, because they are in large part culturally determined. Although they serve as indicators for the distribution of diversity on a landscape, variety names do not always accurately reflect genetic distinctiveness. For farmers, the uses and origins of different crop types along with their unique traits often play a more important role in distinguishing between crop varieties. While this may present complications to researchers and breeders who have long operated using the variety concept, the use of farmer designations for diversity is lending greater insight into farmer management of crop genetic resources. Farmers use traits not only to identify varieties, but also as the basis for selecting and valuing planting materials. In order to construct more nuanced diversity indices, many of the studies described in these briefs take variety names as an entry point, connecting them to distinguishing traits and work by breeders or geneticists.

The reproduction system of a crop is a key feature to consider when grappling with taxonomies and nomenclature. The structure of a crop's biodiversity depends to some extent on its reproduction system. Maize is an extreme example of a highly cross-pollinating crop. In the Mexico case studies (Van Dusen 2006; Dyer 2006), while high costs prevented researchers from relating farmer names for varieties to genetic analyses through seed samples drawn from each household, what would have been achieved from this exercise is not altogether clear. Using neutral molecular markers to assess genetic diversity, geneticists working in Mexico have found that the variation within a sample of maize seed from a single farmer is greater than the variation among farmers in a community (Pressoir and Berthaud, 2004). While some differences in genetic structure can be visualized among communities in terms of the agromorphological characteristics over which farmers exert selection pressures, the results of such selection are not easily identified by molecular analysis. Pressoir and Berthaud concluded that a maize landrace should not be considered as a separate entity, but rather as an open genetic system. By contrast, it is often comparatively easy to identify genetic structure in seed samples of self-pollinators such as rice and wheat.

Crop biodiversity in perennial tree crops is differentiated from that found in annual crops. Like bananas and potatoes, most fruit trees and grapes are clonally propagated, which is more difficult than seed reproduction, but produces a perfect genetic likeness. There are fewer individual plants of perennial crops in each garden, but often more varieties and species than in the case of annual crops. Instead of living for one season, perennial plants can live for 20 to 30 years. The longevity of perennial plants has the consequence that decisions affecting genetic resources may be made infrequently, and that resources may be inherited or leased to other individuals.

In some cases, farmers do not name varieties, referring instead to the crop name, the name of the farmer who manages it, or an attribute that it possesses. The last case best describes the practices of the coffee growers surveyed in Ethiopia by Wale and Mburu (2006). These farmers did not name their coffee types, except to differentiate types introduced from outside the region (called '*Project*'), and those maintained locally (called '*Begeja*'). Within these two broad categories, farmers distinguished individual coffee plants by their production attributes. Moreover, research in Morocco indicates that sets of traits used to describe a variety may have higher consistency across different geographical areas than variety names (Sadiki et al. 2005).

The complexity of local taxonomies is indicated by the examples of counts of diversity units over changing spatial scales and crops, drawn from case studies conducted in Nepal, India, Uzbekistan, Uganda, Peru, and Italy (see Table below). Not only do taxonomies include crops of different improvement status, they represent the diversity of a wide range of production systems. These include systems in which landraces predominate with some coexisting modern varieties, those in which modern varieties dominate with some coexisting landraces, and a wide range of intermediary forms. Moreover, within these varied production systems, diversity is distributed in different ways. For example, sites in India demonstrate high levels of diversity across communities rather than on individual farms, whereas in Peru high levels of potato diversity are still found on

Table 1—Diversity across countries

Country	Crop	Crop reproduction system	Counts over spatial scales and diversity units
Nepal	rice	highly self-pollinating	40 landraces and 20 modern varieties in two ecosites 1.55 landraces per farm 1.33 modern varieties per farm
Uganda	banana	vegetative	95 varieties in 27 communities 1-27 varieties per farm 1-5 use groups per farm 0-18 cooking varieties per farm 13-38 varieties per village
Uzbekistan	fruit trees grapes nuts	vegetative	7.1 total varieties per farm 4.9 fruit andnut species per farm
India	sorghum pearl millet finger millet minor millets	range of self-and cross-pollination rates	5 millet crops grown 63 varieties in 60 communities 4 modes of variety improvement: • landrace • hybrid • improved open-pollinated variety • improved pureline selection 1-2 millet crops per farm 1-3 varieties per farm
Peru	potato	vegetative	54 varieties in 13 communities 1-10 per farm
Italy	durum wheat	self-pollinating	33 varieties grown in 8 regions 3 modes of variety improvement: • landrace • old improved • new improved

Diversity Across Countries.
Source: Smale 2005.

individual farms. In contrast to both India and Peru, diversity in Uganda is found on the farm, village, and regional levels. The complexity of these patterns indicates that the development of taxonomies often requires detailed knowledge of local production systems, and their surrounding environments.

Working with Variety Attributes

In addition to striving to achieve a better understanding of diversity, applied economists have begun to more explicitly model the demand for variety attributes in order to explain production decisions and crop diversity at the farm level. This provides insights in terms of crop traits to target for introduction or conservation in local communities.

An Attribute-based Index: An Example from Ethiopia

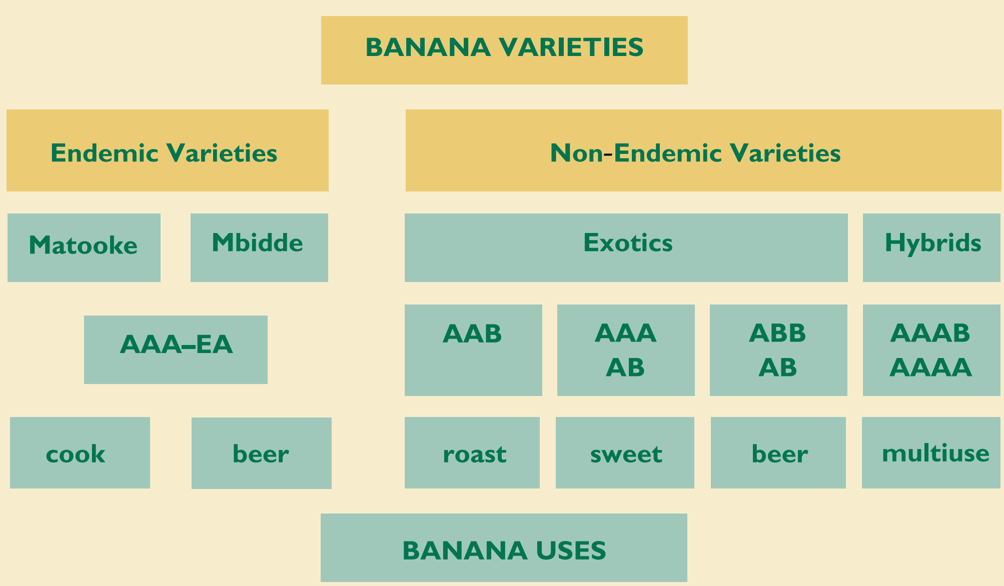
When deciding which trees to maintain and which to replace in Ethiopia, coffee farmers surveyed by Wale and Mburu (2006) indicated that they base their decisions on the attributes of the trees. In this context, the researchers chose to measure diversity in terms of a count of attributes rather than a count of varieties. The premise of their analysis is that the greater the number of coffee attributes desired by farmers, the greater will be the coffee diversity maintained on farms (Bellon 1996). How the count of attributes identified by farmers relates to the genetic structure of the crop is not known. Attributes are expressions of single or multiple genes in interaction with environmental pressures. The crop attributes that are considered by farmers may be interlinked genetically.

In research carried out in eight Peasant Associations in the Jima Zone of southwestern Ethiopia, an important center of commercial coffee production, farmers were asked to rank the importance of coffee attributes in use and replacement decisions. Attributes ranked most highly were agronomic or production-related traits, such as yield potential, disease resistance, yield stability and environmental adaptability. Research findings support the hypotheses that market access, labor and land endowments, the importance of coffee in farm production relative to other crops, and farmer attitudes toward risk significantly influence farmer demand for coffee attributes. As a result, the attribute-based index can be employed to predict which farmers in a community and which communities are most or least vulnerable to the loss of distinct crop types of functional importance to them.

Modeling Demand for Variety Attributes: Bananas in Uganda

If attributes are the criteria that farmers use to select their planting materials, a next step in understanding farmer management decisions is to evaluate how those attributes affect the combinations and numbers of varieties grown. One study first elaborated a taxonomy that utilizes information about genomes, end-uses, plant descriptors and names, and then employed an attribute-based model of variety demand to help explain patterns of banana diversity on Ugandan farms (Edmeades et al. 2006). In that study, the authors hypothesized that the relative importance of attributes to growers, given dif-

Figure 1— Banana taxonomy in Uganda



Banana taxonomy in Uganda.
Source: Edmeades (2003).

ferences in provision of the attributes among use groups and varieties, affects on-farm banana diversity.

Uganda is one of the largest producers and consumers of bananas in the world, as well as being a second center of banana diversity. A large number of distinct clones of an endemic type are grown in Uganda, as well as a number of exotic, unimproved types and a few recently developed hybrids.

A great richness and evenness of banana varieties are found at the household, village and regional spatial scales. Econometric analysis supports the perspective that on-farm diversity results from the advantages and disadvantages of particular banana varieties in regard to cooking quality, plant disease and pest pressures. For example, growers who assign importance to resistance to common pests and fungal diseases are likely to grow a larger number of more evenly distributed banana varieties on their farms. One explanation for this may be that diversifying varieties may enhance tolerance to biotic pressures and maximize expected yields in banana groves.

In looking at diversity within use groups, the story is slightly different. Bunch size, along with cooking and beer quality are also significant factors for use group diversity. The use group to which a banana belongs partially reflects its genomic group, and hence its genetic make-up. In situations where there is more demand for attributes related to cooking quality, households tend to grow bananas from fewer use groups, reflecting the importance of meeting subsistence requirements. The availability of large stocks of diverse planting material is positively associated with greater richness of varieties and use groups on individual farms, suggesting that on-farm diversity is constrained by the local supply of planting material. Indeed, banana planting material is bulky and difficult to transport, and farmers often travel long distances to procure disease-free plantlets.

Future Directions

The findings of these case studies underscore the importance of variety attributes in explaining the decisions of growers. In addition, they emphasize that looking at diversity in different ways provides different answers to the question of why farmers choose to grow certain varieties.

Further work is needed on how to construct taxonomies so as to bridge the gap between different ways of perceiving diversity. In an attempt to more accurately depict the factors affecting farmer decisions about crop varieties, economists have frequently been compelled to use what are considered by geneticists to be relatively rudimentary diversity metrics. On the other hand, attempts to link molecular studies of crop populations to the socioeconomic factors that shape the management of diversity have frequently resulted in a lack of distinguishable patterns.

Linking the economic factors underlying farmer decision-making with more sophisticated molecular studies may require working at different scales. The diversity metrics employed in research in this area will need to reflect the scale of analysis, starting at the farmer level with units such as use-groups, and changing as broader geographical areas and increasing sample sizes permit socioeconomic and molecular patterns of diversity distribution to become visible.

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RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 15

Crop Diversity and Economic Change

Melinda Smale and Amanda King

As isolated communities have become progressively more linked into global production systems, understanding the impact of economic change on crop diversity has become increasingly important. Although there is little conclusive evidence, it has been hypothesized that processes of economic change and market integration pose some of the greatest threats to crop genetic diversity. With better access to markets and rising incomes, the attributes associated with diverse crop varieties are more easily replaced with purchased inputs and goods. Processes of economic change alter the ways rural people earn their living, removing some of the incentives and knowledge needed to produce diverse crop varieties, thus contributing to genetic erosion.

Concerns about the impact of economic change are not new. Starting during the early green revolution period in the 1970s, economists assumed that the introduction of superior seeds would lead farmers to plant all of their crop area with modern varieties. However, landraces of major crops such as rice, wheat, and maize are still grown in a number of places where they outperform modern varieties or have unique traits that farmers value (Smale 2000). Improved varieties are scarce or nonexistent for many so-called "minor" crops that may be of local economic value but not global commercial value. One of the goals of this research is to provide new evidence regarding the impact of economic change on the values that farmers ascribe to their crop genetic resources.

Changes in Product Prices and Income

Mexico is a center of origin and diversity of maize. One persistent assertion by researchers studying maize landraces in Mexico is that the greatest threat of genetic erosion is the unprofitability of maize production, rather than the displacement of landraces by modern varieties. Dyer revisits this question in his study, undertaken in the context of maize price and income changes induced by the North American Free Trade Agreement (NAFTA) (2006).

Mexico's total cultivated area of maize peaked in the mid 1960s, but rising input costs and reduction in subsidies led to stagnating production in the 1990s. Fierce protection of the maize sector had long characterized Mexican food policy and politics, and the support price of maize remained well above international prices throughout the 80s, benefiting commercial growers, but leaving subsistence farmers adrift. In 1994, the government initiated the liberalization of the maize sector under NAFTA, with the idea that phasing out support prices and removing trade barriers would allow maize imports from the US to fill a growing gap between domestic supply and demand.

Surprisingly, the domestic supply of maize has remained above the record 1990 level since the initiation of NAFTA, and the cultivated area of rain-fed maize rose throughout the 1990s. Subsistence growers on rain-fed lands have not benefited from subsidies for commercialization, and many appear to operate at a loss. Clearly, farmers in these

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marginalized areas—where landraces are the norm—continue to value maize cultivation above the market price of maize grain alone.

Why did market integration not have the anticipated effect on growers of maize landraces in Mexico? To answer this question, Dyer solicited the responses of farmers in the Sierra Norte de Puebla to hypothetical "shocks" to the maize market, consisting of changes in maize price, or income (in the form of government transfers). His findings show that responses to maize price and income changes depend on the type of grower and household characteristics. Increases in the price of maize raise the value of production for large growers, who respond by increasing their demand for land in maize. Although price increases also affect subsistence households, the non-market benefits, or shadow value of production, make small-scale growers less likely to respond to price increases. The study suggests that the decisions of maize farmers in Mexico's rain-fed areas are associated with both market and non-market benefits. According to Dyer, an important follow-up question is how farmers respond to policy-induced income or price changes by choosing among competing crops and economic activities.

Labor Markets and Migration

One perspective on the impact of alternative economic activities is offered by Van Dusen (2006), who studied how labor markets influence crop diversity at the household level. The labor market in Mexico is strongly affected by migration, both national and international. While temporary migrants can return to their villages, invest remittances into their own farms and enjoy consumption of household products, international migrants are removed from local production altogether, thereby drawing labor out of maize production. This has important consequences for farmer maintenance of crop diversity.

Van Dusen's approach is outlined in Brief 13. He examined the Mexican *milpa* system in the Sierra Norte de Puebla, considering the richness of bean, squash and maize varieties grown on individual farms. His findings demonstrate that migration affects crop diversity in complex ways. Remittances from temporary migration help increase crop biodiversity levels, offsetting the negative effects of reduced labor availability. Off-farm income from employment elsewhere in the region reduces *milpa* biodiversity, drawing labor out of the *milpa* for longer periods of time. Higher frequencies of permanent migration at the village scale, as well as more extensive membership in US migrant networks, reduce the biodiversity levels observed in individual *milpas*. As villagers leave rural areas, the importance of minor crops and varieties declines, along with the availability of labor to maintain them.

Returning to the issue of why small-scale farms in Mexico continue to grow maize despite it being unprofitable, Van Dusen's findings indicate that families are able to continue maize production by subsidizing it with migrant remittances. Two other findings of his study shed light on the role of human capital, or labor quality, in maintaining crop diversity. Both more years in school and greater use of an indigenous language are positively related to *milpa* biodiversity. That is, *milpa* biodiversity appears to be reinforced by both formal and indigenous knowledge.

Competing Production Activities

Economic change is not simply a process of integration into markets, but often involves a change in the ways in which people earn their living. Policies and programs to support rural development and reduce rural poverty seek to intensify and diversify agricultural production at the regional scale, to enhance opportunities for participation in nonfarm activities and to promote market integration through improved rural infrastructure. A study by Winters and colleagues (2006) used household data on potato producers in Cajamarca, Peru, to examine the relationship between diversification in agricultural income sources and the genetic diversity of potato.

According to Winters and colleagues, the greatest threat to on-farm crop diversity may not be replacement by modern varieties, but rather shifts in resource use away from the production of farmer varieties. Winters and colleagues hypothesize that potato diversity in Cajamarca is threatened by a shifting of patterns of land use and labor allocation toward production of agricultural commodities, and in particular, dairy farming, a highly profitable activity.

As hypothesized, the study findings indicate that households that are more intensely involved in milk

production and whose share of nonfarm income has increased are less likely to maintain potato diversity. Those households that intensified potato production were also associated with lower levels of diversity. On the other hand, wealthier households maintained higher levels of richness and evenness among potato varieties.

The above findings from the Cajamarca region of Peru raise the question of whether a reduction in genetic diversity in centers of crop diversity is a necessary consequence of rural development. It may, for example, be feasible to halt or reverse these trends by promoting the consumption and transformation of native varieties, most of which are not known in the market, particularly if there is sufficient demand for them. If rural development is incompatible with on-farm diversity, careful consideration must be given to how and when in the process of rural development to intervene to support genetic diversity.

Economic Transition

Economies in transition bear some similarities with developing economies in terms of the high costs of transacting in markets. In Hungary, home gardens played a critical role in food security during the socialist period when markets were run by the state (Birol et al. 2006). Home gardens are homestead fields adjacent to family dwellings that are essentially fixed in size. During the period of agricultural collectivization and state ownership (1958–1989), families were allowed to cultivate these fields privately. The few extant landraces in Hungary are found in home gardens, and home gardens continue to be tremendously rich per unit area in terms of crop species and varieties, as well as indigenous livestock breeds.

Today, rural households in Hungary still rely on home gardens to enhance the breadth and quality of their diet, but many experts predict that accession to the European Union may lead to a loss of home gardens. Birol and colleagues (2006) hypothesized that farmer demand for home gardens will decrease as Hungary's economic transition proceeds. To test this hypothesis, they used several approaches, including the stated-preference approaches mentioned in Brief 13 (see also Brief 17 for institutional analysis). Comparing and contrasting these approaches provides insight into the impact of economic change on opportunity costs and private values of rural households, and the future of home gardens in Hungary.

In the study, four key components, or attributes of agricultural biodiversity in home gardens were analyzed and valued: 1) crop variety diversity, 2) crop genetic diversity, 3) agrodiversity, and 4) soil microorganisms. The total number of crop varieties (richness) is used as the indicator of diversity. Cultivation of a landrace serves as a proxy for crop genetic diversity. Agrodiversity refers to whether the family integrates crop and livestock production. Soil microorganism diversity relates to the use of organic production methods. Research was undertaken in three regions of Hungary that differ in terms of agroecological and infrastructure features, and where pilot programs have been launched to protect environmentally sensitive areas.

The findings confirm that farmers in more economically developed, less isolated settlements choose to depend less on home gardens for food security, and prefer lower levels of agricultural biodiversity. Moreover, the value of individual components of agrobiodiversity varies by region. For example, while crop and livestock integration is valued across all regions, areas with access to market infrastructure, denser population settlements, and higher levels of commercial and social development tend to place less value on landraces grown in home gardens. Conversely, the demand for home gardens is greater in settlements situated at greater distances from market towns, and in areas with high unemployment rates and therefore a greater need for food self-sufficiency.

At present, more isolated and less developed farming communities are the least-cost options for public programs aimed at sustaining current levels of agricultural biodiversity on farms in Hungary. However, the opportunity costs and private values estimated by

Table 1—Estimates of the willingness to accept (WTA) compensation for home garden attributes in three Environmentally-Sensitive Areas (ESAs) (in Äper household per annum, in 2002 prices[a])

Attribute	Dévaványa	Örség-Vend	Szatmár-Bereg
Crop variety diversity	--	–111	–141
Landrace	--	–95	–83
Agrodiversity	–404	–100	–198
Organic production	–235	--	–76

Source: Birol 2004.
(--) Demand for the attribute is not statistically significant at 5% level.
[a] 1€ = 267.52 HUF, June 2003.

goals related to social equity might be suitably addressed through integrating traditional Hungarian home garden management practices into national conservation programs in selected sites, with selected farmers. One feasible, publicly financed mechanism is the National Agri-Environmental Programme (NAEP) of Hungary, which has been recently integrated into the National Rural Development Plan (NRDP).

Birol and colleagues will be sensitive to economic change. Substantial changes are expected to occur in Hungary as a consequence of economic transition and EU membership. Most are expected to augment farmers' access to markets, reducing the dependence of farm families on their gardens for household food consumption and diet diversity. On the other hand, economic development typically progresses unevenly, and the transition to a market economy has so far resulted in growing income disparities and rising domestic prices. The already marginalized localities described here may become even more so. Certain

The Two Faces of Economic Change

Findings from these and other case studies in the collection indicate that as long as there are harsh production environments where markets function imperfectly, rural households will continue to depend on the diversity of the materials they grow to ensure the family food supply. This does not, however, mean that those who maintain crop biodiversity need be "left out" of the process of economic development. The

Table 2—Agrobiodiversity found on Hungarian home gardens by region

	Dévaványa N=104	Őrség-Vend N=110	Szatmár-Bereg N=109
Total number of crop and fruit tree species, subspecies and varieties found in the home gardens in the region	87	114	74
Average number of crop and fruit tree varieties/home garden	17	28	19
Total number of fruit trees (individuals)	1244	1878	4277
Percentage of households that cultivate landraces	3.6	5.5	10
Percentage of households managing both livestock and crops	74	77	76
Average number of large livestock (cattle, pig, sheep, horse, donkey)	11	2	4
Average numbe of small livestock (poultry, rabbit, pigeon, bee)	26	22	37
Percentage of households that engage in organic production	17	16	8

Source: Hungarian Home Garden Diversity Household Survey, Hungarian On Farm Conservation of Agricultural Biodiversity Project, 2002.

relationship of market development and commercialization to crop biodiversity appears to be complex, particularly when considering factors beyond the issue of market access.

Many of the case study findings suggest that factors associated with economic development may not, in the short-term, detract from intracrop and intercrop diversity on farms. In some marginal environments, the introduction of modern varieties broadens the range of materials grown rather than narrowing it. Moreover, higher levels of assets often enhance rather than detract from crop biodiversity. On the other hand, diversification in any form is often associated with labor-intensive production. Rising opportunity costs for farm family members in countries undergoing rapid economic change may lead to less diversity within cropping systems. Permanent migration and off-farm employment may ultimately have detrimental effects on crop diversity.

These findings underscore an essential point: that there will often be better ways to relieve poverty than through the introduction or diversification of crop varieties. While crop genetic diversity is important to the poor—particularly in terms of meeting food and nutritional requirements—supporting crop genetic diversity conservation is not a way out of poverty per se, unless it can be linked to an income-earning activity.

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RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 16

Conservation Objectives and Policy Trade-offs

Melinda Smale and Amanda King

The decision to define or measure diversity in a certain way for conservation or development policy can have unforeseen impacts on other types of diversity. For example, efforts to promote the diversity of one crop in a multi-crop system can lead to a loss or decline of diversity in another crop. A program that enhances the richness of varieties may have unforeseen effects on the evenness in the distribution of those varieties. Similarly, in conserving public-good qualities of diversity, the choice to conserve landraces that are valued by breeders for their rareness may have a negative impact on landraces with other important genetic qualities, such as broad adaptability. Crop diversity may also be affected indirectly by policies that encourage seed interventions to promote another crop.

The types of policy and diversity trade-offs described in this brief are context specific, arising from the particular economic and ecological conditions under which crops are grown. However, generalizations can still be made across studies that have implications for conservation programs and seed-system interventions.

Which Diversity Matters?

Not all landraces can be conserved on farms, and not all farmers can conserve them because of the costs involved. The challenge for many developing countries is to create incentives for maintaining diversity that can benefit both current and future farmers. One way of distinguishing those varieties that provide high public value is to classify them in terms of their use for future breeding. This information can then be linked to data about the farmers and environments with high propensities to maintain these varieties, in order to determine where there is overlap between high private and public values for diversity.

In Nepal, Gauchan and colleagues (2006) identified geneticists' preferences for landraces by classifying them according to three criteria: diversity (a heterogeneous population); rarity (embodying unique or uncommon traits); and adaptability (exhibiting wide adaptation). A farmer decision-making model was developed to identify the factors that influence whether landraces meeting these public-good criteria are grown.

Education, labor composition in the household, and livestock assets are all found to be significant predictors that households will grow landraces that are important for future crop improvement. More adult labor engaged in agriculture has a large affect on the probability that adaptive landraces are grown, while the more endowed a household is with livestock assets, the more likely it is to grow genetically diverse landraces. Human capital also appears to be a critical factor. The more educated the decisionmaker in rice

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production, the greater the likelihood that households will grow a landrace that is genetically heterogeneous. In terms of market-related variables, isolation from markets is associated with higher probabilities of growing a landrace that is identified in terms of all three qualities identified as potentially valuable by breeders. In addition, selling landrace grain is positively associated with growing varieties with rare alleles, suggesting that policies supporting the development of specialized markets might be used to provide incentives for continued cultivation of rare landraces.

Using these results, Gauchan and colleagues statistically profiled farmers with high likelihoods of growing landraces that breeders identify as potentially important. In comparing these household groups with those that are less likely to grow landraces, they found that farmers with more assets and greater rice areas dedicated to landraces are more likely to grow landraces with important public-good qualities. In addition, greater involvement of adults in farm production is positively associated with production of valuable landraces, suggesting that policies that draw labor off the farm may diminish the chances that particular landraces will be grown.

What Scale of Analysis?

In Ethiopia, barley, teff, sorghum and millets are considered "old crops", while maize and bread wheat are relatively new. In comparing the inter- and intracrop diversity among the cereals commonly grown on household farms in the highlands of Ethiopia, three types of potential policy trade-offs may occur, including those that take place between different types of diversity (intercrop diversity), those that prioritize one crop over another (intracrop diversity), and those that support the introduction of modern varieties at the expense of landraces. In two comparable studies, Benin and colleagues (2006) and Gebremedhin and colleagues (2006) analyzed these types of trade-offs at the level of the household and the Peasant Association. The results have implications regarding appropriate strategies to sustain crop biodiversity at different scales.

The household level

At the household level, Benin and colleagues found no apparent trade-offs between policies that would enhance the richness of cereal crops, as compared to the evenness of their representation on individual

Table 1—Statistical profile of households with high and low predicted probability of growing landraces that breeders identify as potentially valuable in Ithe Kaski ecosite, Nepal

Household profile	High predicted probability: Grow diverse landraces	Grow rare landraces	Grow adaptive landraces	Low predicted probability of growing any choice landrace
Family size	6.15	5.8	6.36	5.86
Fraction of active working adults who are men	0.34	0.31	0.33	0.27
Ratio inactive/active persons	0.88	0.85	0.85	1.07
Number of persons working off-farm	1.3	1.35	1.35	1.71
Share of adults working on-farm	0.91**	0.98**	0.83**	0.50
Total value of household assets (NRs)	40043**	39877**	31366**	23408
Total land cultivated (ha)	0.92**	0.91**	0.76**	0.42
Rice land cultivated (ha)	0.75**	0.75**	0.62**	0.32
Landrace share of cultivated rice area	0.91**	0.88*	0.82	0.64
Rice landraces (number)	5.5**	5.35**	4.0**	1.59

Source: Gauchan et al. 2005.

Note: (*,**) denotes statistically significant differences (5%, 1%) between means of households with low and high predicted probabilities.

farms. While different factors are significant in explaining the richness and equitability among varieties grown for any single cereal crop, they are consistent in terms of the direction of their effect on both conservation criteria. In contrast, the factors that determine patterns of intracrop diversity vary among cereal crops and some factors are clearly more important for one crop than for others. For example, policies related to livestock and oxen ownership will affect both the intercrop and intracrop diversity of cereals, but in different ways among different cereal crops. Similarly, farm physical characteristics, market access, population pressure, and regional location are related in varying ways to both intercrop and intracrop diversity of cereals, and hence the impact of policies that influence these variables remains difficult to predict.

There is less ambiguity when looking at the potential impacts of policies seeking to enhance productivity through the use of modern varieties. So far, introduction of modern varieties has not led to the displacement of landraces, most likely because modern varieties have limited adaptation and farmers face many economic constraints. Instead, Benin and colleagues found that it is just as likely that small amounts of seed of modern varieties actually diversify the seed set of farmers by meeting a particular purpose, rather than contributing to uniformity.

The village level

While it is important to understand the trade-offs that occur at the level of individual households, the question remains as to what this household-level information can tell us about maintaining diversity on a larger scale. Particularly in the case of cross-pollinated species, the structure of genetic variation may more closely reflect the combined practices of farmers in a village rather than that of any single household. Because villages have the capacity to govern the utilization and conservation of genetic resources for both private and public objectives, in many contexts the village may serve as the smallest social unit for policy interventions targeted at the sustainable management of on-farm crop biodiversity.

In the highlands of Amhara and Tigray, for example, Gebremedhin and colleagues (2006) found that a combination of agroecological variables, market access factors, and farmer characteristics predicted the variation in the inter- and intracrop diversity at the village level. Their research suggests that in this context, policies aimed at augmenting the richness of cereals would not entail trade-offs in terms of equitability. Different factors are significant in explaining the richness and equitability among varieties grown for any single crop, but they are consistent in sign. This implies that a program designed to conserve the richness of any single crop is not likely to negatively impact the evenness among crops at the village level. The factors that determine the patterns of intracrop diversity vary among cereal crops, and some are clearly more important for one crop than another. As a result, conserving the richness or equitability among varieties of one cereal might lead to less richness or equitability among those of another cereal.

Similar to findings at the household level, there are no apparent trade-offs between the use of modern varieties and the spatial diversity of maize and wheat. Instead, small amounts of seed of improved varieties diversify the seed set of farmers. The continued need for diverse varieties in the highlands of Amhara and Tigray is partially due to the fact that neither the physical terrain, nor the local market networks, are favorable for specialized, commercial agriculture. This is not to say that the improved varieties introduced in such areas are themselves genetically diverse, but rather that the traits they add to the existing trait pool of the other varieties enable farmers to better meet their production and consumption objectives.

Seed Interventions

Another way of understanding the relationship between policy development and crop diversity outcomes is to look at the impacts of particular policies, such as seed supply interventions. Lipper and colleagues (2006) assert that the impact of seed supply interventions on diversity among crops will depend not only on the nature of the intervention (e.g. whether it is aimed at increasing the variety choice or reducing access costs), but also on the features of the local seed system, and farmer demand for genetic services from the crops. They tested this hypothesis by investigating the impact of an NGO-led seed supply intervention on the crop diversity at the household level in Eastern Ethiopia.

In this case, the NGO provided wheat seed in an attempt to reduce the costs of growing wheat, which although well established in the area, was a minor crop and demonstrated little genetic variability. In contrast, sorghum is widely grown in the area and demonstrates considerable local genetic diversity. By grouping both sorghum and wheat into service categories, Lipper and colleagues found that wheat varieties are selected primarily for their productivity, whereas sorghum varieties are selected on the basis of a range of characteristics, including drought and disease tolerance. Because in this context production and consumption objectives are unlikely to be met through market interactions, producers are constrained to growing crops such as sorghum, which can meet a more diverse set of needs.

Farmer participation in the NGO program was found to be positively related to one index of intercrop diversity and increased the area under wheat production. Neither of the two characteristics of the seed supply (seed exchange and the presence of extension) were significant in explaining intercrop diversity, probably because seed exchange increases the availability of varieties of one crop (intracrop diversity), but not the number of crops (intercrop diversity). The authors concluded that the expected impacts of seed system interventions on intercrop diversity will depend on the crop selected for the intervention and its relation to the farming system.

Defining Conservation Priorities

The three diversity indices applied in most of the studies considered here express diversity concepts that translate into three distinct conservation objectives: richness of crops or varieties, evenness or proportional abundance, and relative abundance or dominance. Most researchers have found no apparent trade-offs

that would enhance one type of diversity over another, either at the household or village level. Nor are there likely to be trade-offs in terms of emphasizing one public-good quality over another. As evidence from Nepal demonstrates, many landraces have overlapping qualities that are important for future breeding. On the other hand, trade-offs in policy impact across crops are more pronounced. Programs designed to encourage intraspecific diversity in one cereal crop often have the opposite effect on another crop. Rural development programs also have the potential to indirectly impact diversity by altering farmer incentives, determining the availability of seed materials, and shaping farmer demand for particular genetic services.

While it is difficult to draw generalizations because of the overriding importance of local context, this

Table 2—Frequencies of "service" category selection by crop

	Sorghum		Wheat	
Service	Number of households ranking planted varieties per category	Percent households ranking planted varieties per category	Number of households ranking planted varieties per category	Percent households ranking planted varieties per category
High return	251	51.1	193	74.5
Risk mgmt	212	43.2	36	13.9
Consumption	28	5.7	15	5.8
No service	0	0.0	15	5.8
Total	491	100.0	259	100.0

Source: Lipper et al. (2005).

work does indicate the need to be explicit about conservation priorities. Policies targeted at the maintenance of crop diversity must be developed with an understanding of the various public and private services generated by crop diversity, and the awareness that direct and indirect forces are constantly changing the distribution of genetic diversity across the landscape.

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RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 17

SEEDS, MARKETS, AND INFORMATION

Melinda Smale and Amanda King

Institutional analysis can be used to understand the value placed on crop diversity by farmers as a social process, and to uncover the market-related constraints and incentives that influence farmer management of genetic resources. This is particularly important for capturing the dynamics of crop populations and the collective impact of individual decisions regarding crop diversity.

In the applied economics literature, the notion of a seed system has often been limited to the "formal" seed industry, which uses public or private funding to develop, multiply, and distribute finished varieties as certified seed. Informal seed systems, documented mostly by anthropologists or sociologists, are often treated as marginal to the process of economic development. Given the range of materials planted by farmers in centers of crop diversity and the concern about introducing new varieties, studying only one segment of the seed system in isolation of the other could lead to biased conclusions.

Several of these case studies seek to advance the understanding of seed system interactions with crop biodiversity levels, including both formal and informal systems. They define seed systems to include all the channels through which farmers acquire genetic materials and information about those materials, including farmers' organizations, weekly markets, and social networks. Analyses are not limited to certified seed of modern varieties, but encompass all types of material planted locally by farmers.

Seed Replacement and Variety Change

Replacements and transfers of seed are critical for buffering against biotic stress and genetic deterioration, and are a measure of diversity over time. Recent studies have started to focus on the role of seed systems, and markets in particular, in order to capture more about the temporal dynamics of crop diversity and its spatial distribution over a larger geographical scale. For example, research in Andhra Pradesh and Karnataka, India, by Nagarajan and Smale (2006) confirms the hypothesis that along with the characteristics of households, farms, and product and labor markets, local seed system characteristics also influence the crop biodiversity managed at the level of the *panchayat* (literally, "village community"). In the study, characteristics of local seed markets are defined and measured by crop, including both seed transfer rates from farmer-to-farmer transactions, and seed replacement ratios.

The findings demonstrate that there is a relationship between seed replacement ratios for millet crops and improvement status. Namely, farmers replace seed more slowly for farmer varieties than for improved types, and replace hybrid seed more frequently than seed of either improved open-pollinated varieties or improved pureline selections. Farmers supply their own seed to other farmers less often than they replace it, and transfer rates are highest for minor millet crops, for which there is no formal seed system.

Another important finding is that the velocity of seed flows in *panchayats* is positively correlated with the spatial richness and relative abundance of major and minor millets.

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The trade of larger quantities of seed through shandies is associated with greater diversity in minor millet varieties. Similarly, greater volumes traded through seed dealers are linked with the richness of pearl millet varieties and do not lead to the dominance of any single variety. In other words, high turnover within the seed market, both in terms of velocity and quantity, does not induce variety specialization in this environment, but rather supports the range of millet crops and varieties grown.

Institutional analysis also provides significant details about the nature of the seed system. In this context, seed supply channels are differentiated by the improvement status of the genetic material, though all categories of millet genetic resources change hands at the level of the village trader and shandy. Nagarajan and Smale found that although the flow of seeds and grains through shandies is thin, the product turnover is high. As is often found in informal, local cereal markets, traders often do not differentiate between seed and food grain or between seed types. Another surprising finding is that although family and friends are the major sources of original and replacement seed, as well as being recipients of transfers, almost all exchanges are monetized, at least in terms of "token money." Seed dealers also serve as a vital link between farmers and seed suppliers (public seed corporations and private companies).

Seed Systems and Social Institutions

What kinds of social institutions are involved in providing households with access to planting material and what is their effect on crop biodiversity? In Central Asia, home gardens have served as repositories of agricultural genetic resources for hundreds of years, reflecting cultural traditions and contributing to the local economy. Although the Soviet modernization of agriculture led to centralized planning of widespread monocultures on vast irrigated acreages, farmers maintained significant diversity in household garden plots. After the break-up of the Soviet Union, home garden production became even more pronounced in the newly formed Central Asian nations such as Uzbekistan, where land tenure laws forced households to diversify their income-earning activities in order to survive the economic transition. A range of local organizations and social groups interlink households, supporting their access to goods and information.

Van Dusen and colleagues (2006) explore this relationship between household production and social institutions in describing the biodiversity of fruit trees, grapes and nuts in a rural economy in transition. They found that in addition to planting their own seed, saplings, or rootstock, farmers also obtain these materials via a system that involves heterogeneous institutions such as informal local village networks, the bazaar, and official sources such as the national plant breeding institute. Households obtain most materials locally, from within the same village or the same district.

Within the same village, different households follow distinct strategies to obtain agricultural information as well as planting material. Almost half of households reported using only one institution, and of those, the majority used only the bazaar. Households using a greater number of institutions are less likely to use the bazaar and more likely to use a combination of institutions. "Agricultural information" is the term used to describe the knowledge required to properly cultivate a plant, and includes information such as which varieties are pest or drought resistant, the watering schedule of a variety, and the maturation date of a variety. It can also include social information such as plant uses, market prices, and transportation characteristics. In the local seed system, agricultural information is conveyed through individuals, and consequently the norms regulating the conditions under which people meet can influence the type and quantity of agricultural information passing between farmers.

Statistical analysis of data from Samarquand, Uzbekistan, reveal a link between the extent of a community's participation in social groups and the levels of fruit and nut tree diversity managed by households in home gardens. No relationship is found between the type of institution used to obtain genetic material and the level of diversity in orchards. Household participation in community groups does, however, influence the type of institution to which households look for planting material.

Seed Systems and Economic Transition

Institutional analysis can also be used to understand the incentives and constraints imposed by international agreements, and the competing interests of stakeholders. Using a stakeholder analysis, Bela and colleagues (2006) sought to identify the historical patterns and contemporary institutions that shape not only perceptions of crop diversity, but also the constraints on farmer decisions that have arisen with Hungary's entry into the European Union.

Using a variety of methods, the study identifies and describes different groups of farmers with regards to their attitudes, values, and landrace cultivation practices. This textual analysis uncovers a crucial point for the future of on-farm conservation in Hungary and elsewhere: confusion over terminology impedes the definition of a common policy problem, and hence blocks stakeholder cooperation. Stakeholder interviews present a fragmented picture regarding national views on which plant genetic resources ought to be conserved, and the utility of conservation. For example, in discussing which genetic resources should be conserved, representatives of the formal seed system used all of the following terms: landrace, old variety, traditional variety, straggling variety, primeval variety, and Hungaricum. Some stakeholders gave the same meaning to all the listed terms, while others differentiated among the terms. Apparently, neither the specialized scientific literature on landraces nor the legal regulation of plant genetic resources has managed to forge a consensual terminology in Hungary. Meanwhile, farmers described no fewer than eight notions of landraces: 1) old variety; 2) variety named after the farmer who reproduces the seed (e.g., Gerõ's bean); 3) variety named after characteristics of the plant (e.g., color or shape of the grain); 4) variety named after the place of origin (e.g., specific landscape or village); 5) variety with no specific name, as compared to high yielding varieties; 6) variety with an indefinable name, such a "baktipaszuly"; 7) parents' varieties; and 8) primeval varieties.

While the institutional arrangement to support *ex situ* conservation of plant genetic resources is relatively effective and well-managed in Hungary, on-farm conservation efforts face an unsupportive and adversarial legal and policy context. The Hungarian legal and policy setting provides no incentives to farmers to undertake in situ conservation of plant genetic resources; rather, it encourages them to use commercial, high-yielding varieties offered by the formal seed market. None of the actors operating in the formal seed system have a financial interest in promoting the conservation of plant genetic resources. The heart of the problem is not only that the informal, local seed system of farmers is not operating efficiently, but that it is delegitimized by the current legal and policy framework. As a result, there is no cooperation among stakeholders to form an effective lobby or joint policy platform for the preservation of genetic resources.

Bela and colleagues conclude that the general demographic, social and economic trends prevailing in Hungary are contributing to the erosion of plant genetic resources. The social status of farming is low and the cultural cohesion of rural communities is deteriorating as economic opportunities become restricted in rural areas. Two concrete recommendations emerged from the stakeholder interviews. One is to utilize landraces in organic farming because the use of varieties well-adapted to local agroecological conditions is essential for organic farmers. The organic seed market is currently characterized by excess demand, which is mainly a consequence of domestic legal regulations. The other recommendation is to establish rules governing the trade and exchange of landraces. Some stakeholders believe that landraces need not enter commercial trade, arguing that it would be more sensible to provide the option of using them in a closed system, while not excluding farmers who plant landrace seed from government subsidization programs. Under this scenario, a farmer producing a landrace in larger amounts as a commodity would be required to register it. Some of the interviewees suggested a registration system similar to the French "amateur list" of varieties. In general, the research suggests that given the institutional context for landrace production in Hungary, the process of genetic and cultural erosion may only be halted if effective public policy is developed to provide incentives for continued conservation by farmers.

Seed Systems and Cooperative Marketing

Market institutions influence crop diversity both by providing material and by transmitting consumer demand for products back through the market channel to farmers. Crop varieties differ in their provision of product characteristics, such as protein content, color, and grain moisture or humidity, all qualities that matter to food processors. Especially in wealthier, industrialized economies, consumer demand for differentiated products can support a demand at the regional level for crop varieties with particular traits.

In southern Italy, for example, agricultural cooperatives play an important role in the production, processing and marketing of durum wheat. After the 1950 Agrarian reform, the agricultural sector in the south was partitioned into very small landholdings tenured by a multitude of owners. Production cooperatives were formed in order to overcome difficulties associated with this structural arrangement.

Di Falco and colleagues (2006) found that in southern Italy, cooperative concentration is associated with higher levels of durum wheat diversity. Consumer demand for a range of wheat-based food products drives processing industries to acquire several varieties of crops, each with a slightly different com-bination of properties. The cost of the market infrastructure that supports this differentiation is borne by consumers in the European Union. In addition to supplying the goods and attributes demanded by consumers, these marketing institutions have the positive, but probably unintended, side effect of supporting regional diversity levels. Other forms of marketing institutions actively protect unique product qualities or production processes. In general, the success of marketing institutions in supporting diversity on farms depends on the capacity of producers to control supply, the existence of efficient marketing channels, and the sustained consumer demand that accompanies rising incomes. For this reason, challenges faced in developing economies with lower income levels are much greater.

Future Research Directions

While it is known that the supply of seed through markets is a significant factor that sometimes enhances and sometimes detracts from crop biodiversity, considerably more work is needed to develop concrete, generalized policy recommendations. A stronger analytical framework is needed to better comprehend the role of local markets in seed systems, the relationship of local markets to other seed system institutions, and the impact of the seed system institutions on farmers' access to genetic material. By analyzing seed system interventions, more can be learned about the possible trade-offs and synergies between agricultural development and in situ conservation.

The diverse range of institutions on which these studies focus—ranging from seed systems to marketing corporations to government bodies involved in agricultural sector policy development—emphasize the important roles played by various institutions in terms of providing an overarching context for farmers' decisions regarding crop genetic resources. The findings demonstrate the need for further analysis of the institutional context for the production of crop genetic resources in conjunction with other economics-based methods for assessing value. In particular, they highlight the value of bringing methods and knowledge from other areas to bear on economic studies of crop biodiversity, including sociological and anthropological concepts and methodologies.

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RESEARCH AT A GLANCE

Genetic Resource Policies

What is Diversity Worth to Farmers?

Brief 18

Targeting Conservation Policy

Melinda Smale and Amanda King

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Analysis of the determinants of on-farm crop diversity not only enables researchers to predict the distribution of diversity across landscapes, but also to develop programs or recommend policies that might positively affect its conservation. This can be accomplished in two ways: either directly, or through policies that influence factors linked with higher levels of crop diversity. Throughout the case studies that we have explored in this series, several salient factors appear to be linked in major ways to the local production of diverse crop genetic resources. These factors, discussed in more detail below, provide possible entry points for policy to support both conservation and rural development.

Environmental Heterogeneity

Much past research has demonstrated the strong relationship between diversity in ecosystems and diversity in crops and varieties, as farmers seek to optimize their management of environmental niches (Brush et al. 1992; Zimmerer 1997). The research summarized in this series, which encompasses a number of countries and continents, confirms this hypothesis, repeatedly demonstrating that factors such as the quality and heterogeneity of soils, land elevation and slope, the number of plots, and farm fragmentation are often positively associated with varying crop biodiversity levels. For example, farmers in Nepal maintain more diversity when they own and cultivate different land types, choosing a broader set of varieties to suit multiple classes of farmland and seasonal niches. Similarly, villages in Amhara and Tigray, Ethiopia, with extensive eroded land tend to grow more cereal crops that are evenly distributed across the agricultural landscape. The consistency of the findings regarding the links between crop diversity and environmental heterogeneity should encourage policy makers to target environments where, in addition to meeting food and income needs, crop diversity serves an important ecological function.

Human Capital

A number of variables related to human capital, which is crucial for social and economic development, are related in a positive way to crop biodiversity levels. The level of education of the household head or production decision-maker is consistently associated with higher levels of crop biodiversity on farms. In Ethiopia, literacy levels in the farming community affect diversity positively across all cereal crops, in some instances to a large degree. Moreover, women's education or participation in agricultural activities, where measured, appears to be positively related to intracrop, or variety diversity. This finding is consistent with hypotheses from the literature about the gender division of labor and women's responsibility in food preparation. In poorer countries and marginal environments in particular, policies that support education, particularly for women, are also likely to support the maintenance of diverse crops and varieties.

In most countries, with the exception of Ethiopia, crop biodiversity levels are higher when production decision-makers are older or more experienced. Thus, crop diversity could be placed at risk as older generations fail to pass on their knowledge or values to a younger generation of farmers. On the other hand, in more industrialized agricultural economies such as that of Hungary, there has been a resurgence of interest in landraces as part of a movement towards organic farming. The studies indicate that policy initiatives that enhance the exchange of varieties and information about varieties can facilitate the continuity of crop-related knowledge between older and younger generations.

Financial Capital

Almost all of the studies indicate that there is a positive relationship between household wealth and levels of crop biodiversity. In one respect, this finding, combined with the evidence regarding human capital, reminds us that in harsher farming circumstances, those who have more are able to do "more." In many of the countries studied, it is the better-off households with more labor, more assets, more land and more wealth that grow landraces. This finding suggests that conservation programs may have social equity consequences. Targeting households that are more likely to maintain valuable landraces is not necessarily equivalent to targeting the poor. Local conservation initiatives might have greater probabilities of success, in fact, when *not* working with the poorest households, unless they are focused on providing access to genetic materials or related resources.

Social Capital

Much of the value of crop genetic resources is derived from the socio-cultural context in which crops are grown. Farmers frequently draw on social capital to support local crop diversity, particularly through the exchange of planting materials and information within local community groups, social networks, and seed system institutions. In Samarquand, Uzbekistan, for example, statistical tests uncovered a statistically significant association between the extent of household participation in social groups and the level of fruit and nut diversity in home gardens. Community institutions ranged from interactions with limited financial or social obligations, such as weddings or teahouse meetings, to more intense bonds of social commitment, such as work brigades and reciprocal exchange groups. Given their role in planting material replacement and information exchange, further research is needed to articulate and support the link between social groups and crop biodiversity in household farms.

Another instance in which social capital has been shown to affect crop biodiversity is the case of Mexico, where migration was found to affect diversity through both income and labor market effects. While long-term and permanent migration appears to draw labor away from agricultural production, short-term migration within Mexico appears to be associated with higher levels of *milpa* biodiversity through the additional income provided by remittances. Social networks often have a powerful influence on both the incentives and the capacity of farmers to grow diverse crop varieties, although the effects of such networks may be indirect.

Seed Supply

As discussed at length in Brief 17, seed supply factors, which were introduced in the Peru, southern India, and Eastern Ethiopia case studies, have only recently been incorporated into analyses of the determinants of crop diversity. The research results indicate that there is a positive correlation between seed supply variables including modern varieties, and crop diversity levels. In the millet-based systems of southern India in particular, seed system factors were found to significantly affect the level of variety diversity in almost all regressions. The average seed replacement ratio was found to be positively correlated with the spatial richness and relative abundance of varieties of major and minor millets in villages of Andhra Pradesh and Karnataka. Moreover, greater seed volumes traded through local weekly markets enhanced the diversity of minor millet varieties. The preliminary findings of these studies suggest that an array of new topics about seed systems and crop biodiversity remain to be explored, particularly in areas where both formal and informal seed systems play important roles in seed supply.

Future Research Directions

While the studies described in these briefs have made significant advances in terms of reaffirming the importance of specific factors for the continued production of crop biodiversity, other factors still require further investigation. For example, the exact nature of market failure remains a mystery. As researchers begin to disentangle specific components of markets, the fundamental hypothesis that market isolation drives on-farm conservation appears less and less informative. Understanding the role of seed systems, and particularly supply interventions, is critical for researchers involved in efforts to raise agricultural productivity without sacrificing crop biodiversity.

Another important issue related to studies of crop biodiversity is the geographical "scale" or level of analysis. Although this was treated in some of the studies by mixing variables measured at the household farm, village, settlement or community level, future work should continue to focus on how diversity metrics, conceptual approaches and variable measurement should be adapted to new levels of observation and analysis. Variation across communities may be as or more important for program design than variation within any single community. For analysis to generate useful information for program design, prior knowledge will be required regarding whether it is more efficient to sustain crop biodiversity levels for the average household, among targeted households, or at the level of a larger social and biological unit.

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Table 1A—Determinants of crop biological diversity on household farms, by case study

Country (Chapter)	Household					
	Age or experience, household head	Education, household head	Women's eduation or participation	On labor, family size	Other income, transfers, migration	Wealth
Ethiopia (6)						
intercrop	0	0	-	+	0	+
intracrop	-,+	+	+	+	+,-	+,-
Ethiopia (4)	0	0		+		-
Ethiopia (14)	0	0		0	0	+
Uganda (7)	+	+	+ [a]			+
Nepal (10)	+	+	+,-	+		+
Peru (9)	0	0		0	-	+
Uzbekistan(12)	+			0	+	+
Mexico (5)	+ (-)	+		+	+,-	0
Hungary (8)						
intercrop	0	0		0	0	+,-
intracrop	+(-)			+		+,-

Table 1B—Determinants of crop biological diversity on household farms, by case study

Country (Chapter)	Farm: Farm size	Farm: Good quality land, moisture	Farm: Elevation, slope	Farm: Number of plots, fragments	Markets	Seed supply, including modern varieties
Ethiopia (6)						
intercrop	+	0	0	+	0	
intracrop	+	-,+	+,-	-	+,-	0
Ethiopia (4)	0			+	-	
Ethiopia (14)	+	+	+		-	0,+
Uganda (7)	0	-	-	+	+,-	+
Nepal (10)		+		+	+,-	
Peru (9)	+(-)	-	+	+	-	+
Uzbekistan(12)	0					+
Mexico (5)	+		+	0	+,- [b]	
Hungary (8)						
intercrop	+	+			-	
intracrop	+	-			0	

Source: Smale 2005: 285

Note: + indicates statistically significant, positive direction of effect on coefficient of variable in econometric regression; - indicates negative effect; +,- means both directions of effects observed for different equations; (-) indicates that second order effect is decreasing; 0 indicates no effect; blank indicates that the factor was not measured or was not relevant to the study.

[a] Effect if banana production decision-maker is a woman.

[b] In particular, labor markets.

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Genetic Resource Policies

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